Adelaide Botanic Gardens – Waterways Study

FINAL REPORT

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1 INTRODUCTION

This report outlines an investigation into the waterways and water use within the Botanic Gardens of Adelaide (the Gardens). It presents recommendations to improve the ecological health of the waterways, reduce flooding in and around the Gardens, reduces downstream pollutant loads and options to reduce potable water used to irrigate the Gardens.

The Adelaide Botanic Gardens are the most visited cultural attraction in South Australia. They provide an education resource as well as being an important recreational and cultural icon of Adelaide.

The waterways study was commissioned to support the development of a Masterplan for the Gardens that will set the framework and future direction of the Adelaide Botanic Gardens and Botanic Park (adjacent to the gardens to the north).

An overview of the area is shown in Figure 1.

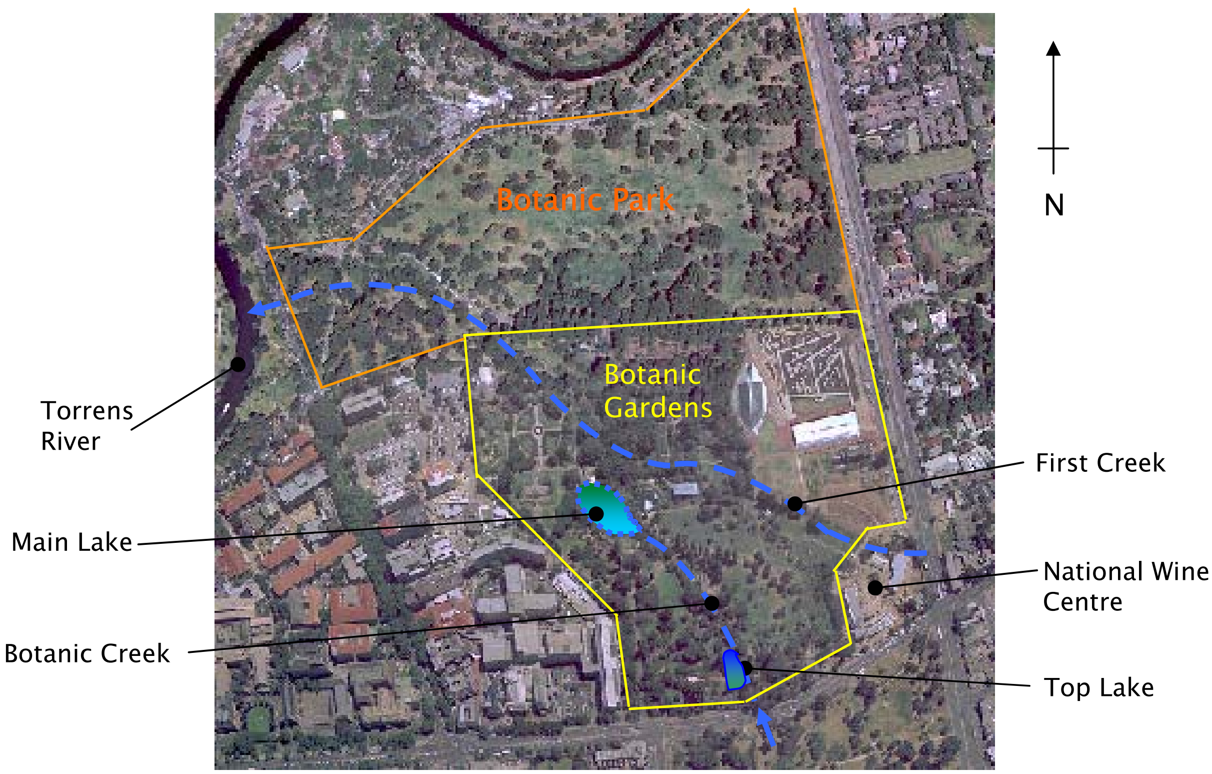


Figure 1: Aerial view of the Adelaide Botanic Gardens and Botanic Park

1.1 Study Objectives

The objectives of the waterways study are to:

- Investigate and address peak flow management through the Gardens
- Consider options for stormwater capture and reuse

- Recommend options for improved water quality, biodiversity, visual, landscape and heritage values of First and Botanic Creeks and the Torrens River.

2 BACKGROUND

There has been a long history of flooding in the Gardens, dating back to 1855 (Byrne, 2003). The Gardens were sited on land that was swampy and often inundated after rainstorms causing erosion of the watercourses and sediment deposition in the Gardens. In response to the frequent flooding the waterways were straightened and channelised and high flow diversions built along Botanic Creek over a 100 year period. These efforts have had mixed success at addressing the problem.

Urbanisation throughout the First and Botanic Creek catchments has increased the proportion of rainfall that become stream flows in these areas and thus increased flooding flows and velocities. A severe event in December 1993 led to the Medical School of the University of Adelaide being flooded. This is thought to have been derived from flows from Botanic Creek through the gardens (Tonkin, 1995). This event highlighted the persistent flooding issues with the waterways within the Gardens despite the significant engineering works on straightening and channelising the watercourses in the Garden. The ‘engineered’ form of First Creek and Botanic Creek adds little to the aesthetic and ecological value of the Gardens.

This study therefore, examines the flooding issues and explores ways to enhance the ecological values of the creeks in the Botanic Gardens and the downstream Torrens River.

Figure 2 shows an overview of the issues associated with the waterways in the Gardens.

Figure 2: Overview of Adelaide Botanic Gardens waterway conditions

3 FLOODING ISSUES

Two watercourses traverse the Gardens, ie. First Creek and Botanic Creek. The catchment areas of these two creeks are 19 km^2 and 3 km^2 respectively. Figure 3 shows the catchment boundaries of First and Botanic Creeks (from Tonkin, 1989).

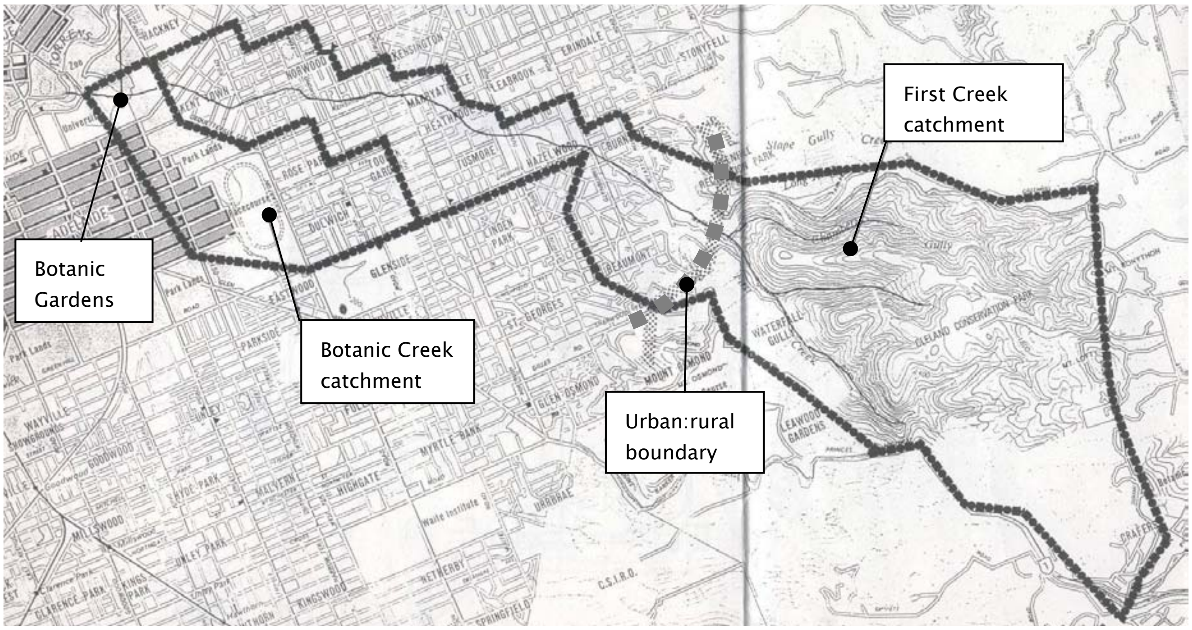


Figure 3: First and Botanic Creek catchments

First Creek enters the Gardens from the east flowing under a culvert at Hackney Road. Previous flood studies have suggested that the capacity of this culvert corresponds approximately to the 20 year ARI peak discharge. Flood flows in excess of this capacity flow in the northerly direction along Hackney Road and discharge into Botanic Park, flowing along local depressions in the easterly direction and rejoining the main watercourse of First Creek in the vicinity of the Zoological Garden.

Botanic Creek enters the Gardens from the south at Botanic Road. Low flows are discharged into a small lake (referred herein as Top Lake) while floodwaters are first diverted towards First Creek along concrete culverts. Previous flood studies have suggested that the capacity of this diversion is approximately 3 m^3/s. Flood flows in excess of this capacity overtop the diversion structure and discharge into Top Lake and thence along a concrete-lined channel into a larger lake (referred herein as Main Lake). Outflow from Main Lake is via a grated overflow structure connected via a underground pipe (diameter to be determined) to First Creek, outfalling in the vicinity of the north-western corner of the Gardens. Flows in excess of the discharge capacity of the lake outlet structure will overtop the Main Lake and flow in a westerly direction towards the University of Adelaide Medical School adjoining the western boundary of the Gardens.

Flooding issues remain a primary concern of waterway management in the Gardens and flooding impacts include:

- excess flows in Botanic Creek reaching Main Lake and not being adequately discharged to First Creek resulting in overtopping the downstream wall and overflows reaching neighbouring properties (University of Adelaide Medical School) causing flooding damage
- deposition of litter and debris after high water levels (both creeks)
- scouring of banks and deposition of sediment, mainly along First Creek
- safety concerns with high velocities and steep banks in well used areas of the Gardens.

The catchments and details of estimated flood flows are described for each creek in the following sections.

3.1 First Creek

The First Creek catchment is narrow, running from east to west and extends from Cleland National Park through Waterfall Gully to the urban areas of Burnside, Norwood and Kent Town.

Approximately 70 % of the catchment is rural with the lower urban areas comprising 540 hectares (BC Tonkin, 1989). The natural stream converts into an engineered channel and underground pipe system from the start of the urban area in the foothills and then leaves the underground drainage network at the entrance to the Gardens under Hackney Road. It remains an open concrete-lined channel through the Gardens.

Tonkin (1989) estimated the flow rates for the 5 year, 10 year and 20 year ARI events at Hackney Road assuming ultimate development of the catchment. These are shown in Table 3.1 below. They also concluded that the underground system upstream of the Gardens can only accommodate 20 year ARI flows and any flow in excess of this would be transferred, via overland flow paths, away from First Creek (north along Hackney Road). Therefore, the maximum flows estimated for First Creek are the 20 year ARI flows of approximately 22 m^3/s.

Table 3.1 Probabilistic Peak Discharges in First Creek (Tonkin, 1989)

Average Recurrence Interval (ARI)	5 year	10 year	20 year
Flow rate (m^3/s)	11.5	16.5	22.3

Estimates of peak discharges for more frequent events were derived from the above figures and are as shown in Table 3.2.

Table 3.2 Estimates of Peak Discharges for frequent events in First Creek

Average Recurrence Interval (ARI)	3 month	6 month	1 year	2 year
Flow rate (m^3/s)	3.0	4.6	6.6	8.7

3.2 Options to reduce flooding along First Creek

Key flooding issues in First Creek are related to the impact of high flow velocities on channel erosion and deposition of sediment on areas adjacent to the watercourse. Furthermore, the highly channelised watercourse is seen to be an efficient conduit for the conveyance of gross pollutants (litter and debris) generated from the urban areas of the catchment into the River Torrens.

As the existing highly engineered form of the watercourse is already subject to channel erosion, there appears little opportunity to rehabilitate the watercourse into a more natural form without resulting in a significantly wider watercourse. It is important that the primary cause of erosion associated with the frequent occurrences of flood events with excessive flow rates be addressed before rehabilitation of the watercourse can proceed. In this regard, it appears that the management of flood events of high frequency (say the 1 or 2 year Average Recurrence Interval events) is an important flood management objective for First Creek. Similarly, the management of gross pollutant loads generated from the catchment during frequent storm events is also an important consideration in developing a waterway management strategy for First Creek.

Opportunities for flood mitigation works upstream of Hackney Road are limited because of development over and adjacent to the waterway, the underground nature of the drain and the high cost of developed urban land limiting any option to purchase land for flood retardation.

Immediately downstream of Hackney Road, there is an opportunity to investigate the construction of a retarding basin that could reduce the peak flow rates along First Creek. Owing to the size of the catchment, the site is not expected to be adequate to significantly reduce peak flows associated with flood events of average recurrence intervals greater than 1 to 1.5 years. Nevertheless, reducing peak discharges for events up to the 1.5 year ARI discharge is seen as a necessary pre-requisite for other creek works associated with removing the concrete lining and reestablishing a natural bed with riparian vegetation. These measures can not proceed without a high risk of failure associated with existing high flow rates.

Provision for overland flow conditions for events larger than the 1.5 year ARI event (up to the 20 year ARI event) will need to be made as part of the creek rehabilitation plan.

The required size of the retarding basin to retard flows to a rural flow for the 1.5 year ARI is estimated to be approximately 80,000 m^3 requiring a land area of between 2 to 3 Ha. This may be accommodated in this area with earthworks and by removing several trees (would need further investigation and approval). In addition, the flood retarding basin site may impede onto the recently planted grape vines and further negotiation would need to occur.

Establishing a flood retarding basin in this area also offers opportunities to provide a permanent storage of water that could potentially be harvested for reuse. It is also recommended to incorporate a stormwater treatment system as part of the retarding basin/ lake system to maintain the health of the lake and to reduce the incidence of litter and debris accumulations in the basin.

A stormwater treatment system here could also reduce litter, organic material, nutrient and heavy metal loads into Torrens Lake. It would most likely comprise a gross pollutant trapping system, a coarse sediment basin, a wetland treatment system and an open water body (lake). Options for the treatment system are discussed further in Section 4.

3.3 Botanic Creek flooding

Botanic Creek has a catchment of approximately 300 hectares (Tonkin, 1989) with a mix of parklands, residential and commercials areas in the suburbs of Rose Park, Dulwich, Victoria Park Racecourse and some of the eastern area of Adelaide.

Figure 4 shows the catchment of Botanic Creek (from Hassell, 2001)

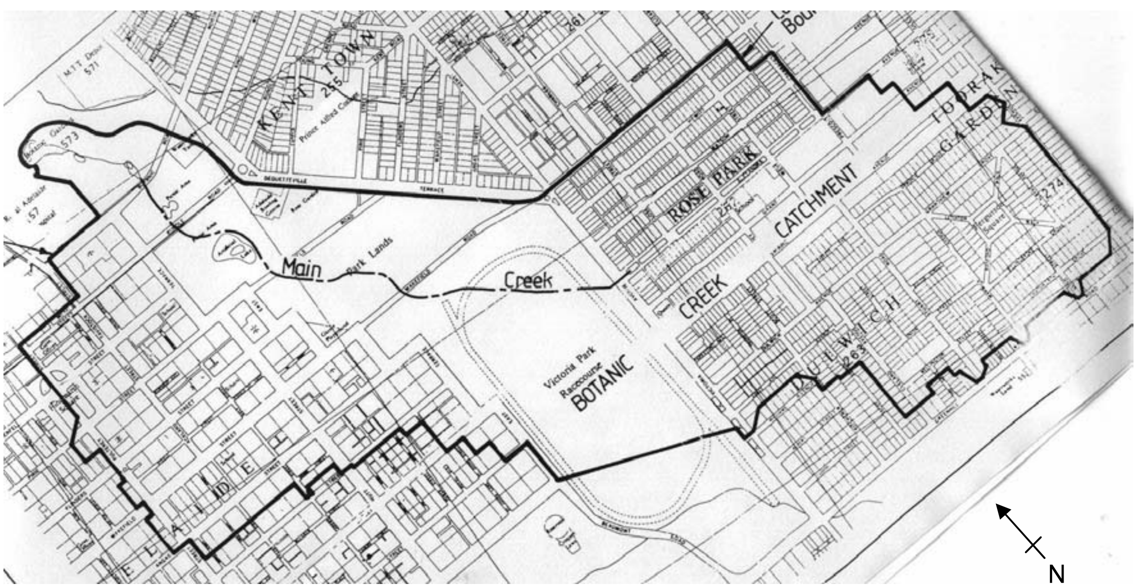


Figure 4: Botanic Creek catchment (Hassell, 2001)

Botanic Creek catchment is highly urbanised and is subject to a very fast response time to rainfall with 'flashy' flows resulting. Tonkin (as part of the Hassell 2001 report) estimate the flows at Botanic Road (entrance to the gardens) to be 5.0 m^3/s for a five year ARI and 6.9 m^3/s for a 100 year ARI.

In their analysis, Tonkin incorporated the possible influence of two road crossings at Wakefield and Bartels Roads on attenuating the flood flows but noted that there is uncertainty in modeling their influence. Removing the influence of these crossing led to modelled peak discharges of 6.0 m³/s for a five year flow and 8.8 m³/s for a 100 year flow. These estimates are considered upper limits of probabilistic flows.

The flow arrangements of Botanic Creek within the Botanical Gardens are a mix of low flow and high flow diversion and overland flow paths. A schematic of the flow arrangements are shown in Figure 5 that indicates an estimated flow of between 4 m³/s and 6 m³/s will need to be conveyed by Botanic Creek downstream of the diversion to First Creek during the 100 year ARI event.

With the outlet at Main Lake having a discharge capacity of approximately 1 m³/s, it is likely that flooding around the lake and overflow across the area to the north west will occur for events larger than the 5 year ARI event. This is consistent with the analysis by Tonkin (1995) of a flood event in late 1993 (that caused flooding to the University of Adelaide Medical School) that suggested that the storm was approximately a 5 year ARI flood event. They also suggest that blockage of the Main Lake outlet caused an increase in the flooding likelihood of downstream properties.

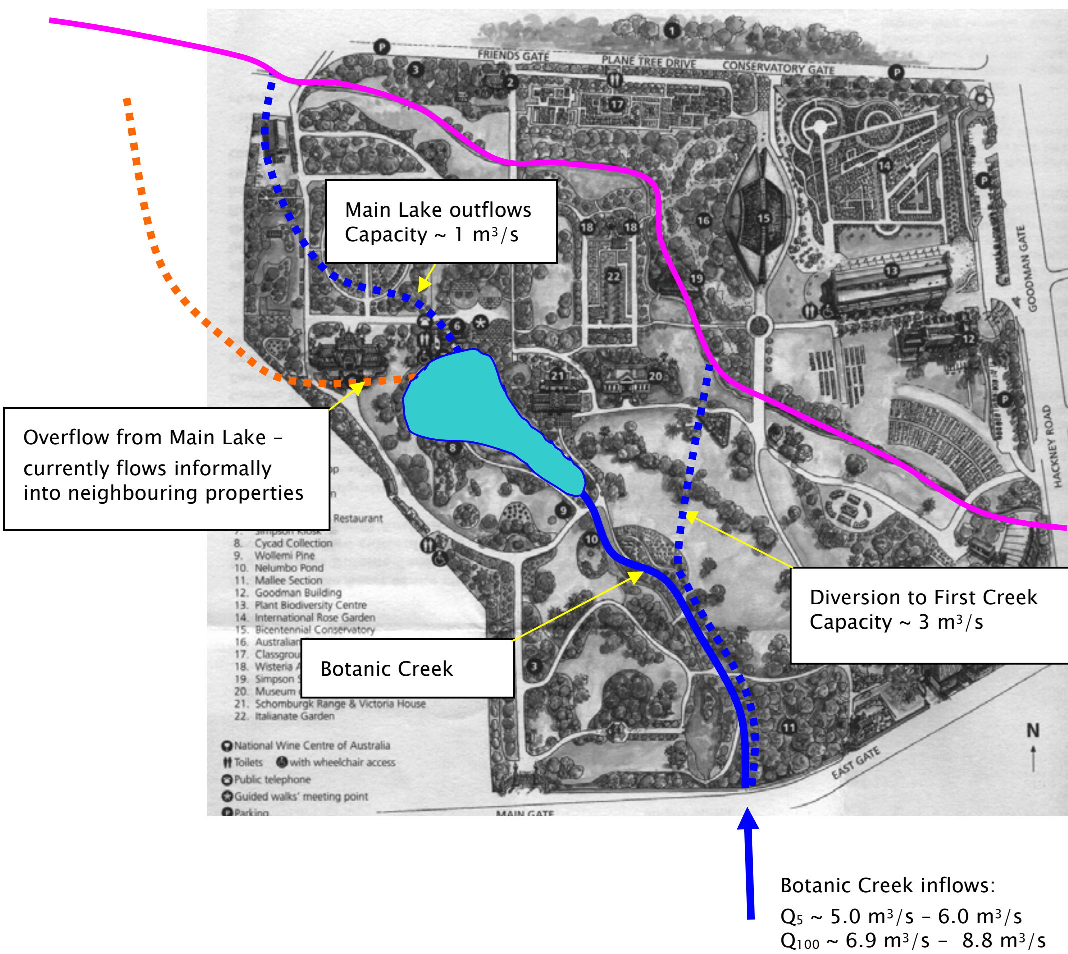


Figure 5: Schematic of the current flow conditions of Botanic Creek inside the Gardens

In managing flooding from Botanic Creek, it will be necessary to consider a combination of management measures including flood retardation and provision of an overflow path from the Main Lake. The next sections recommend some remedial works to address the flooding issues.

3.4 Options to reduce flooding along Botanic Creek

Unlike the primary management objective for First Creek, the main objective of flood mitigation measures in Botanic Creek is to reduce flooding in Botanic Creek to protect adjoining properties from overflows from Main Lake. The level of protection will need to be the 100 year ARI event, consistent with current industry standards. Measures proposed include the construction of an overland flow path downstream of Main Lake, constructing flood retarding basins upstream of the Gardens and providing a blockage free outlet from Main Lake.

3.4.1 Overland flow path

A previous study (Hassell, 2001) identified a potential overland flow path to the north west of Main Lake. This is considered to be an appropriate way to minimise the flooding of adjoining properties and safely deliver overflows from Main Lake into First Creek.

Hassell (2001) propose a approximately 16 m wide grassed trapezoidal channel and embankment to protect adjoining properties. It may be possible to reduce the size of this overland flow path, and to create a more natural watercourse (designed as an ephemeral creek bed planted with suitable vegetation) along this flow path, by implementing other measures upstream and within Main Lake. This will require upstream flood retardation measures to be implemented.

Flood retardation options to reduce the magnitude of overflows from Main Lake during the 100 year ARI event include one or a combination of the following:

- constructing retarding basins upstream of the Gardens
- ensuring the lake outlet does not become blocked during flood events.

These are discussed more in the following sections.

From a water management perspective and to create another waterway as part of the Gardens, an option of diverting low flows from Main Lake to create flows along a natural watercourse/ephemeral creek constructed within the overland flow path should also be considered. The existing outlet could be raised slightly to allow for low flow diversion to the proposed natural watercourse. The capacity of the existing outlet would be maintained as the first point of flood overflow before the remainder of flood flows (above the 1 m^3/s capacity) overflows the lake and are conveyed along the proposed overland flow path.

A potential cross-section of the overland flow path is shown in Figure 6. It shows how different riparian zones could be created along the meandering low flow stream bed. These areas could support different vegetation types as part of the Gardens while still providing adequate flood conveyance during large events.

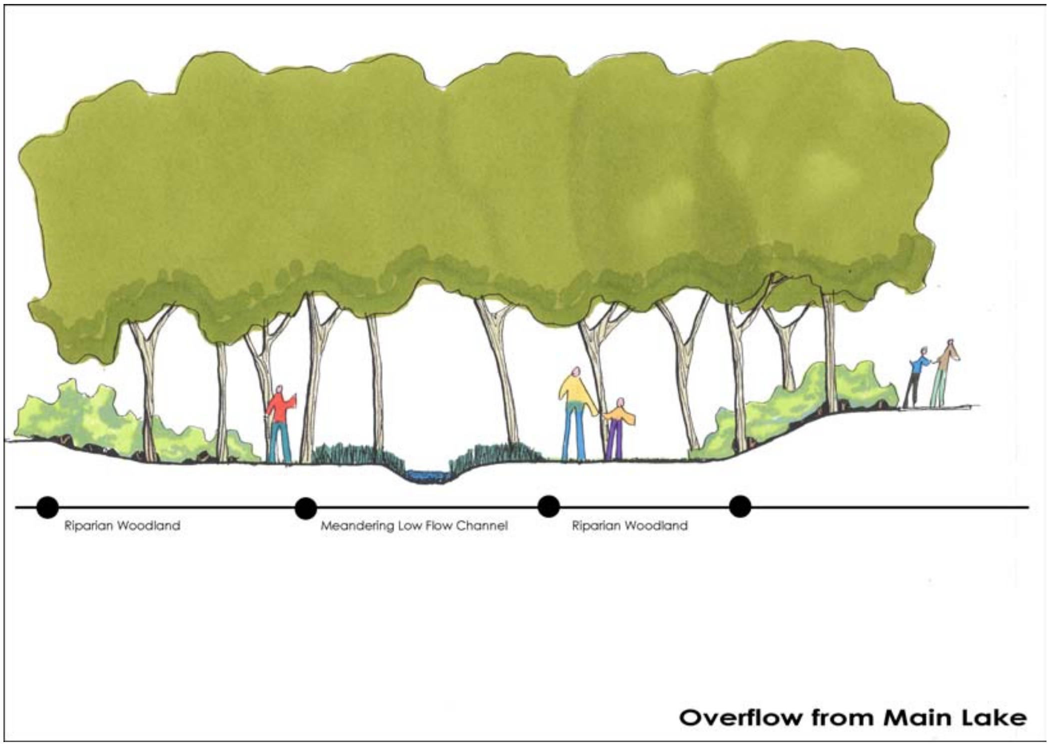


Figure 6 Cross-section of proposed overland flow path from Main Lake to First Creek

3.4.2 Retarding basins upstream of the Gardens

Two sites appear to be suitable for retarding basins upstream of the Gardens and in fact may already operate as informal retarding basins currently (as suggested by Hassell, 2001). The sites are:

- Victoria Park (upstream of Wakefield road)
- Upstream of Rundle Road

Wakefield Road site (~7000m^3)

Natural topography upstream of Wakefield Road would lend itself as a retarding basin with minimal construction. Analysis of the site topography would allow an estimate of the available volume of storage. The area is currently parkland with scattered trees. Modifications to the road culvert could ensure that this area regulates downstream flows and retards large floods.

The photograph is looking upstream from Wakefield road and shows the scattered trees and parkland setting.

Rundle Road site (~8000m^3)

Between Rundle Road and the wall of the artificial lake upstream, of Rundle road is a large depression that may be suitable as a retarding basin. Rundle Road has a significant embankments over the creek (approximately 3-4 metres) with large culvert conveying flows under the roads to regulate flows. There is a potential to use this embankments as flood retarding basins by modifying the culverts under the roads. The potential area that could contribute to the retarding basin includes the area between Rundle Road and the downstream lake embankment between Bartels and Rundle Roads.

The locations of these potential retarding basins are shown in Figure 8.

3.4.3 Improve Main Lake outlet configuration

Tonkin (1995) suggested that blockage of the lake outlet contributed to the flooding of adjoining land. To reduce the likelihood of outlet blockages an alternative design of the outlet should be considered.

The photograph shows leaves accumulating on the grated outlet, with likely blockage with increased leaf loads.

A submerged outlet could be constructed to reduce the blocking of the outlet by floating material. A submerged outlet pit could have a configuration as shown in Figure 7. This would take flow from below the surface and direct it into the existing outlet pipe.

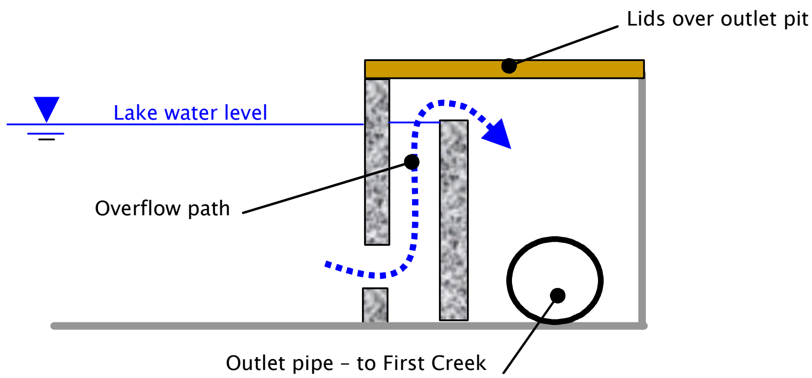


Figure 7 Potential arrangement for Main Lake outlet structure

The outlet capacity of Main Lake could also be reduced by clogging of the underground pipe connecting the outlet structure to First Creek. It is recommended to conduct an inspection of the pipe to First Creek to ensure it is not blocked or it's capacity is not reduced with the incident of tree roots or other obstructions.

3.4.4 Summary of flood mitigation options for Botanic Creek

A range of options could be employed to reduce the flooding risks associated with Botanic Creek. These include:

1. Providing an overland flow path from Main Lake to First Creek (as an emergency overflow). This could potentially be an ephemeral creek system with appropriate channel form, vegetation and stablisation structures and this would support areas of riparian vegetation along the creek.
2. Provide upstream retarding basins – either upstream of Wakefield Road and / or Rundle Road – to reduce the peak discharges into the Gardens.
3. Modifying the outlet of Main Lake to ensure operation in high flow events. Also the conditions of the outlet pipe from Main Lake to First Creek will need to be checked to ensure that does not impede the discharge capacity of this system.

Figure 8 shows potential location for flood retarding basins along Botanic Creek.

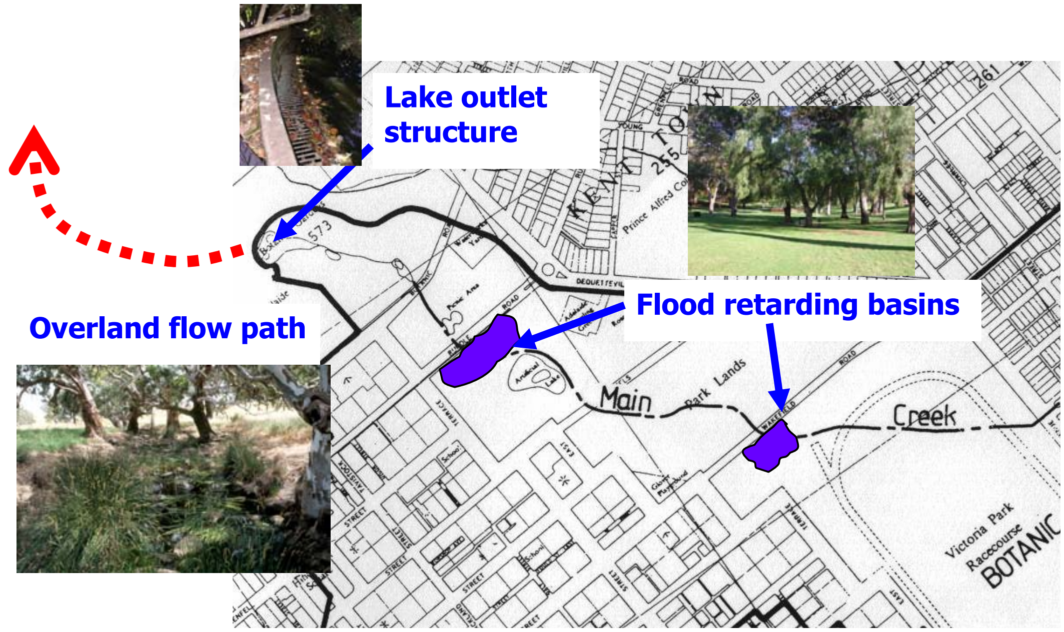


Figure 8 Flood management options for Botanic Creek

4 STORMWATER QUALITY TREATMENT

Stormwater flowing through the Botanic Gardens is expected to carry large quantities of pollutants derived from the urban catchment upstream. Of particular concern to downstream waterways (Torrens Lake) are large amounts of litter, organic material as well as heavy metals and nutrients.

First Creek, in its current form, is a hydraulically "efficient" stormwater drain and the majority of the stormwater pollutants are expected to be conveyed to Torrens Lake. In the previous section of this report, a retarding basin was proposed for managing peak flows of frequent flood events to facilitate the rehabilitation of First Creek into a more natural form. There is a further opportunity for the development of an integrated stormwater treatment and harvesting system to be incorporated into the retarding basin. This section of the report examines treatment options for flows through First Creek at the entrance to the Gardens, adjacent to the National Wine Centre.

Botanic Creek upstream of the Gardens is a vegetated channel that would tend to retain organic matter and litter as well as coarse sediments and there is a gross pollutant trap (GPT) installed under Botanic Road. This would act to capture coarse material prior to it entering the Gardens. However, there was some evidence of poor water quality in Top Lake during an inspection and some water quality treatments are proposed to maintain the health of Top and Main Lakes.

4.1 First Creek stormwater treatment

A stormwater treatment system for First Creek is proposed to be integrated with a flood retarding basin (see Section 3.2) proposed for immediately downstream of Hackney Road. The system proposed is shown in Figure 9 and consists of four stormwater treatment components, these are:

1. Gross pollutant trap to capture litter and debris
2. Coarse sediment trap to remove gravel and coarse sediments
3. Constructed vegetated wetland system to retain nutrients, fine sediment and associated pollutants such as heavy metals
4. Open water body (lake) to provide ultraviolet disinfection and storage from which stormwater could be harvested.

Treated stormwater could then be discharged to storage for subsequent reuse.

The treatment system would be located in the base of the retarding basin and become inundated during floods (when the retarding basin is engaged). This functionality will need to be accommodated in the design of the system to protect scour of collected pollutants and the wetland vegetation. In addition, the structural integrity of the wetland banks during filling and draining of the retarding basin will need to be considered.

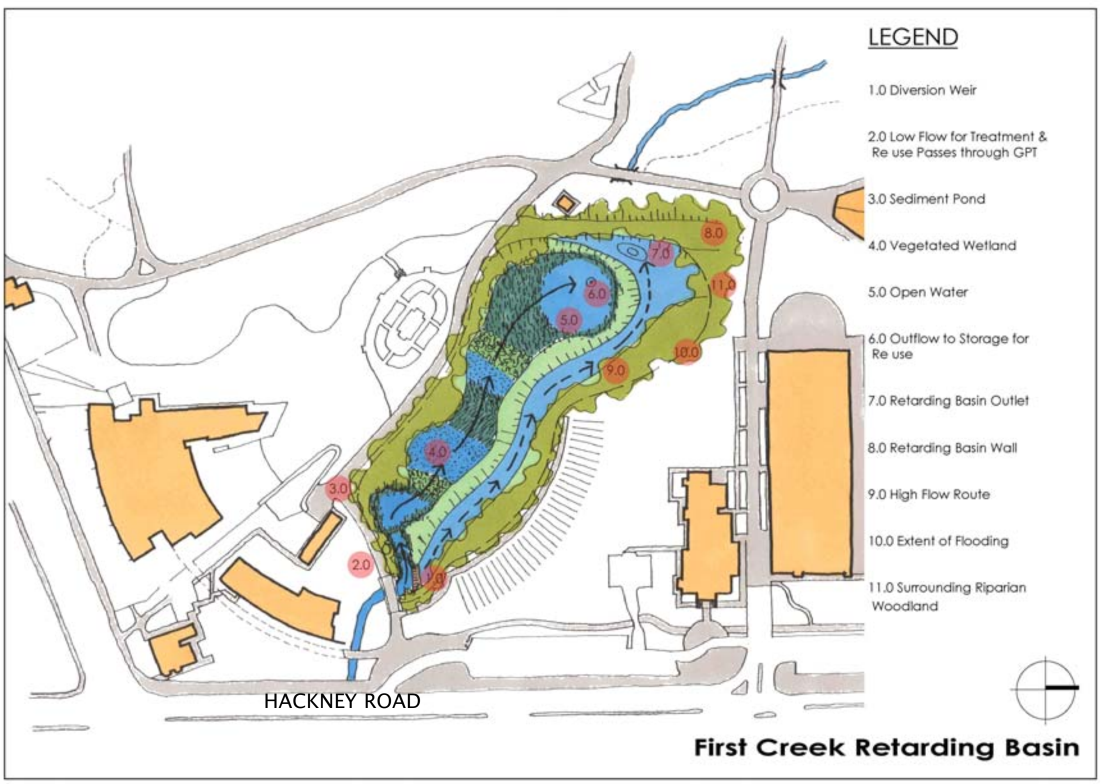


Figure 9 Proposed retarding basin/ stormwater treatment system for First Creek

4.1.1 Gross Pollutant Trap

Recently a trash netting device was installed on First Creek on the downstream side of Hackney Road. However, it was removed as part of the construction of the National Wine Centre because of aesthetic concerns. This left the majority of stormwater from the First Creek catchment untreated and concerns were raised by the Torrens Catchment Water Management Board about the loads of debris reaching Torrens Lake (Tonkin, 2001a).

Tonkin Consulting was commissioned to investigate the feasibility of alternative GPT locations and their highest recommendation was to install an underground GPT in this same location (Tonkin, 2001a). They also recommended some other options of GPTs downstream in the Gardens themselves. In a subsequent report (2001b) they recommend a location immediately downstream of the Gardens in Botanic Park, to exploit an existing drop in the channel bed.

However, immediately downstream of Hackney Road would seem a more logical location for a gross pollutant trap given the integrated treatment system and retarding basin concept proposed for this area. It would also seem logical to construct a GPT on the upstream side of the Gardens so as to protect the waterways within the Gardens from litter and debris.

The design of the GPT will need to be sympathetic to the concerns of the National Wine Centre. There may be a range of alternatives to ensure the Wine Centre is not impacted from the presence of a GPT. Options could include screening the GPT location from the Wine Centre with appropriate vegetation, locating the GPT underground (or under a bridge) or constructing a GPT that has a community art or sculpture value.

The recommendation for a treatment system and retarding basin in this area will require significant earthworks and construction, therefore through clever design there may be options to 'hide' the GPT from the Wine Centre.

GPT in Huntingdale, Victoria

Should suitable site conditions allow for excavation of the retarding basin site, it may be possible to create a drop in the channel bed at the GPT site (ie lower the bed of the retarding basin). This would allow a GPT to be constructed that could use this drop to maintain a blockage free screen, thus allowing efficient operation.

Litter is pushed down the screen, thus leaving the gaps free for water to flow through it.

This concept of GPT was first used in South Africa on very large catchments with success. Similar GPTs have been built in Melbourne with the performances being monitored. The mode of operation is for untreated stormwater to fall down an inclined screen with water flowing between bars and the debris moving along the screen to a holding bay at the base. The screen is meant to be kept free of debris by the force of the water moving the debris down the screen. South African testing suggests an optimal angle for the screens of around 45 degrees.

Containing collected litter and debris at the base of the rack could be in a variety of ways, including a concrete chamber or using nets. Consideration would need to be given to cleaning methods, available space and operation in flood conditions (ie. to minimise remobilisation of pollutants).

Should a channel drop prove difficult to achieve (following detailed survey and investigation of the retarding basin) alternatives such as trash nets could be used. These would also need to be screened from view of the wine centre.

4.1.2 Coarse sediment basin

Large quantities of coarse sediment are expected to be generated and transported thorough the drainage network to the Hackney Road site. Evidence of this is from the history of deposition along the banks of First Creek through the Gardens and at the outlet into Torrens Lake.

A sediment trap (earthen pond) will be required upstream of a wetland system to protect the vegetation from being smothered by coarse sediment. The sediment trap is likely to be an open water body with edge vegetation and integrated with the wetland system (an example is shown in Figure 10). The intention of the basin is to retain the coarse fraction of sediment (down to 0.125 mm) and prevent the bulk of sediment from reaching the vegetated wetlands. The vegetated wetlands are intended to remove a finer fraction of sediments and regulate flow rates into the vegetated wetland system.

Figure 10 Example of an earthen sediment basin with edge vegetation

Maintenance of the sediment basin will be more regular than that for the wetland approximately 2-5 year frequency) and involve dredging of accumulated sediments.

This system will need to account for up to 1 year flows (estimated to be approximately 3.5 m3/s) and be designed to be integral with the operation of the wetland. During large storm events, when the retarding basin operates, the sediment trap will become inundated as part of the retarding basin operation, therefore, vegetation will need to be selected that can accommodate inundation for some time.

4.1.3 Constructed wetland system

A constructed wetland system is proposed to be installed within the retarding basin site just downstream of Hackney Road on First Creek. The primary purpose of the wetland is to treat stormwater to a sufficient level to allow for the water to be stored and reused as irrigation water.

There is insufficient space at the site to design a wetland that would be capable of treating flows from all of the upstream catchment to best practice targets. Therefore, the design intent is to reduce pollutants to an acceptable level for flows that will be stored for reuse within the space constraints of the site. Flows higher than the quantity needed for reuse will bypass the wetlands.

At the downstream end of the site water can be harvested and delivered to storage (either in an aquifer or underground tank) for reuse as irrigation water.

The wetland will compromise of a series of vegetated shallow marshes (ranging in depth from 150 to 450 mm). Water will slowly pass through different bands of vegetation (suited to the different water depths) and pollutants will be progressively removed from the water. The wetland system should be designed with a retention period of approximately 72 hours (ie. it will take 72 hours for water to pass through the wetlands). When the wetland is full, flows will bypass around the wetland.

Maintenance of the wetland will involve vegetation establishment (weeding and replanting) during the first two or three years. Once established the wetland will require occasional litter removal (following flood events that engage the retarding basin) and weed eradication. Approximately every 20 to 30 years collected pollutants in the wetland will be required to be excavated. This will involve dewatering the wetland and excavating collected sediments. The wetland vegetation will then be required to be replanted following this major disturbance.

4.1.4 Open water body

An open water body at the downstream end of the wetland will improve aesthetics around the area and provide temporary storage of water prior to being injected to an aquifer or transferred to another storage. The open water will be a continuation of the vegetated wetlands, but with increased depths that will reduce the extend of protruding vegetation.

4.2 Botanic Creek stormwater treatment

The management of Botanic Creek stormwater quantity and quality are related. A recommendation of the study is that flood retarding basins be developed upstream of the Gardens to reduce peak flow rates. This will not only help flood flow management through the gardens but also help manage pollutants loads to Botanic Creek and Top Lake. A flood retarding basin upstream of the gardens will reduce both natural and anthropogenic litter entering the Gardens.

At the time of inspection Top Lake appeared to have low dissolved oxygen concentrations, the lake was heavily shaded, the water column had a dark and glassy appearance typical of anoxic or low dissolved oxygen conditions. The benthos of the lake also appeared to contain a significant load of partly decomposed leaf litter. Leakage from the weir downstream from the lake supported a biofilm growth of what appeared to be Sulphur bacteria (indicative of highly anaerobic conditions). All these signs strongly suggest that Top Lake has anaerobic sediments and is low in dissolved oxygen.

It is likely that excessive organic loads (both human derived materials and natural leaf litter) reach Top Lake during high flow events that overtop the diversion weir and are deposited in the lake. During inter-event periods, these organic deposits breakdown, reducing oxygen concentrations and potentially resulting in the release of pollutants back into the water column. The use of groundwater to flush Top Lake via the fountain may not result in improved oxygen conditions due to either poor mixing within Top Lake or low dissolved oxygen in the groundwater. There may be a relatively simple solution if the quality of the groundwater was known. For example, groundwater could still be used to manage detention time in the lake (which may well result in reduced water demand), while a re-circulating pump drawing from the lake could be used to operate the fountain and mix the lake.

To further protect water quality in Botanic Creek and Main Lake, the area between Top Lake and Main Lake could be engaged more regularly during runoff events and be configured to operate as a floodplain. This would require some small chokes, (leaky) weirs to be constructed across the flow path. During runoff events flow would be impeded by the weir and spread out behind the weir engaging the floodplain. During low flow periods the leaky weir (a simple rocky riffle, see Figure 11) would allow the floodplain to drain back to the channel. This may require some adjustment of the current vegetation to more closely reflect local riparian zone vegetation. However, this could be undertaken slowly and much of the existing vegetation would be viable under the proposed hydrologic regime.

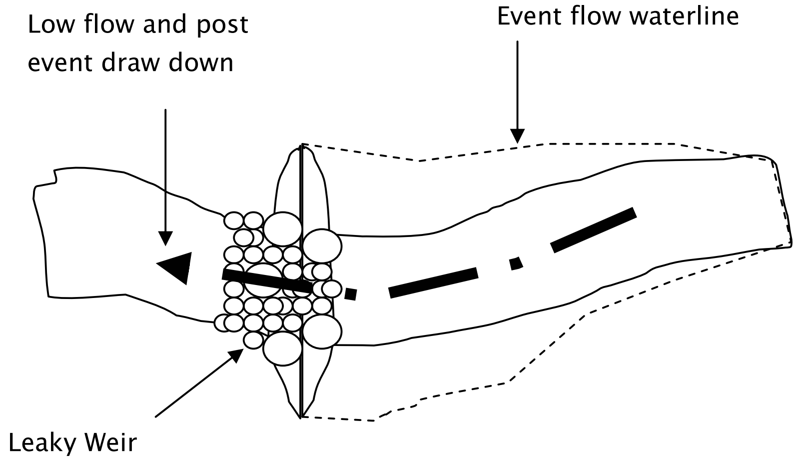


Figure 11 Conceptual diagram of leaky weir to engage the floodplain between Top and Main Lakes

4.3 Summary of stormwater treatment

An integrated system of treatment is proposed for First Creek (shown in Figure 9) to be incorporated within a flood retarding basin just downstream of Hackney Road. This system include a:

- Gross pollutant trap
- Coarse sediment trap
- Vegetated wetland system.

This integrated system will act to protect the Gardens and downstream Torrens Lake from litter and debris as well as sediment and nutrient loads. The design of the treatment system will be incorporated as part of a flood retarding basin located just downstream of Hackney Road. Water passing through the GPT/ wetland system will be treated sufficiently to be harvested, stored and reused as irrigation water for the Gardens.

Botanic Creek offers the opportunity to construct a treatment system that increases the contact of flows with vegetation by constructing leaky weir that spread the flow and increase contact with vegetation in the reach between Top and Main Lakes. This system could be a pool and riffle system that enhances the landscape while providing nutrient reduction of creek flows.

5 WATER CONSERVATION

Large quantities of mains (potable) water are currently used to irrigate the Gardens. This irrigation water could be supplemented with alternative sources of water as it does not need to be of drinking quality. Finding alternative sources of irrigation water for the gardens could reduce the reliance on mains water and save over 100 million litres of drinking water each year. This would also contribute to the sustainability of the gardens.

A way to reduce mains water demand is by matching the quality of the source of water to its intended use. As most of the water used by the Gardens is for landscape irrigation, there are other non-potable sources that may be feasible, these include harvested surface stormwater, reclaimed water or groundwater.

Alternative sources for irrigation water are explored in the next sections with recommendations made for likely potable water savings.

5.1 Current water use

There are three main sources for water use as part of the Gardens, potable water use (for irrigation of the Gardens and building use), river water from the Torrens (for Botanic Park irrigation) and groundwater (for Italian garden water feature).

Indicative quantities of use have been estimated from water meter readings (potable water) and from pumping records kept by the Gardens staff.

5.1.1 Potable water use

SA Water meter readings from a report on water usage (ADC Results, 2001) over a number of years are presented in the table below.

Year	1997/98	1998/99	1999/00	2000/01
Water use (ML)	80.5	123.0	80.0	119.8

As the table presents a peak water use of approximately 120 ML per year is used by the Gardens and almost exclusively as irrigation water (as the temporal plot of the use shows (Figure 12).

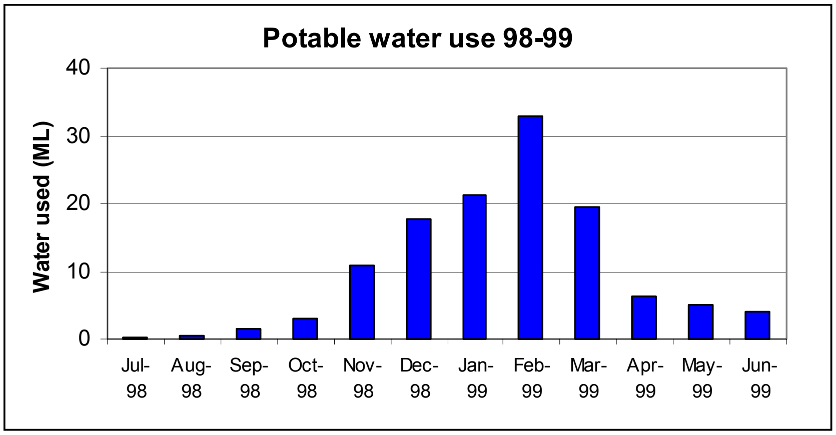


Figure 12 Monthly distribution of mains water use by the Gardens

The temporal distribution of water demand shows the highest demand corresponds with the hottest and driest months. It therefore follows that any reuse system will be required to store collected water for reuse until these drier months (November to April).

5.1.2 Torrens River water use

Pumping records kept by Botanic Gardens staff indicate a usage of approximately 39 ML of water from the Torrens River in 2002/03 year. It can only be assumed this is typical of pumping rates and that a similar distribution as for the potable water use is required (ie. most water required during summer months).Currently there is no licence agreement between the Torrens Catchment Board and the Botanic Gardens to accurately measure these quantities.

5.1.3 Wisteria bore pump

Water is pumped from a shallow aquifer (approximately six meters deep) to supply water to top up water features in an Italian garden as well as supplying a fountain as part of a memorial structure in the top lake.

Pumping rates were estimated by staff as being 76.8 KL/day. This is equivalent to 28 ML per year.

5.1.4 Summary of water use

One of the objectives of this study is to reduce the use of potable water for irrigation. This could be achieved in several ways, firstly reducing the demand for water in general, by planting vegetation that requires less water or through improved application techniques. While these will be valid methods for water conservation, they are considered outside the scope of the current study. This investigation will use the recent irrigation data to investigation non-potable sources.

Currently the water that is extracted from the Torrens River and from groundwater is assumed to be sustainable and not require supplementing from other sources.

To minimise the use of expensive potable water, its supply used for irrigation could be supplemented by other means. The annual usage rates indicate that up to 120 ML per year are used and this quantity Is used to investigate harvesting options. It should be noted however, that in many years less water will be required and also should the gardens move towards more water conservative vegetation.

5.2 Alternative sources for irrigation water

To reduce the demand on potable water supplies for irrigation water (that is not required to be at potable quality) alternative sources of water are investigated. Three main potential sources were considered:

1. Harvesting stormwater
2. Using reclaimed water from wastewater treatment plant (in Glenelg)
3. Extracting groundwater.

These are discussed in more detail in the following sections.

5.2.1 Stormwater (storage vs reliability)

First Creek conveys flows from the foothills of Adelaide through the Gardens and into Torrens Lake. The catchment area is approximately 1500 hectares and each year approximately 2,200 ML of water flows through the Gardens. It would seem, therefore, there is an adequate supply of stormwater to supply irrigation for the Gardens.

Stormwater however, will require storage until it is required. Modeling the system requirements would suggest a storage of approximately 17 ML would be sufficient to supply irrigation water with between 80- 90% reliability. This means that 10-20 % of the water will need to be supplemented with potable water supplies after prolonged dry periods. It is generally un economic to design reuse system with more than 90% reliability.

Figure 13 shows a relationship between the storage size and the reliability of supplying irrigation water to the Gardens for three different demand scenarios (80,100, 120 ML per year). This plot was derived by modeling the rainfall, stream flows and irrigation use over a 10 year period.

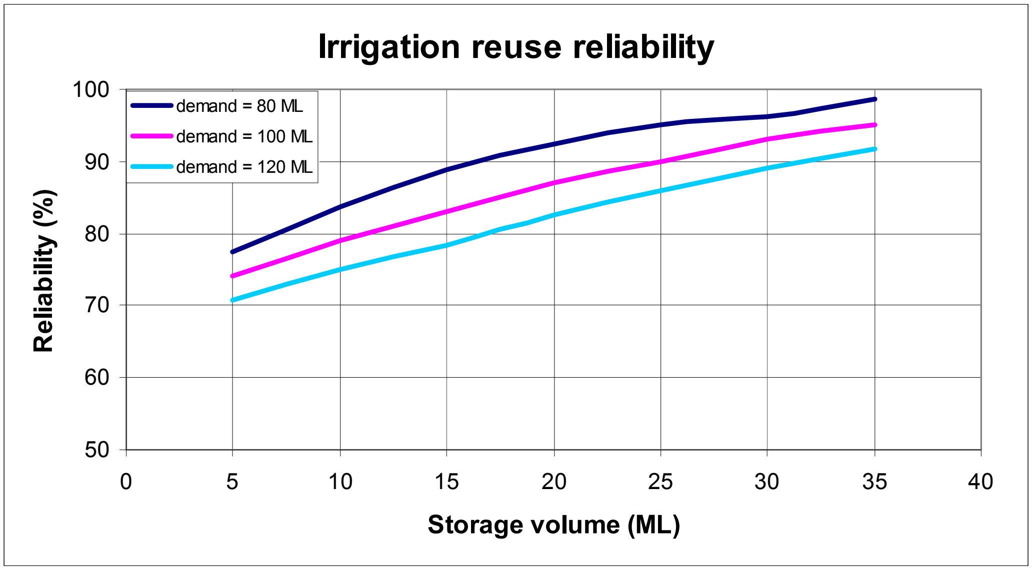


Figure 13 Reliability versus storage size for harvested stormwater from First Creek

To store the stormwater it will require treatment to remove gross pollutants, sediment and nutrients, so that is does not cause any water quality problems in the storage system (either above or below ground). This is particularly important with aquifer storage systems.

5.2.2 Reclaimed water

Reclaimed water is that recovered from a sewage treatment plant. The wastewater has undergone considerable treatment and is suitable for irrigation purposes. Currently there is no reclaimed water system in the vicinity of the Gardens.

SA Water is investigating a reclaimed water system from Glenelg wastewater treatment plant and a potential reticulation system to Adelaide city. Should this system be constructed it could potentially supply irrigation water for the botanic gardens. The use by the Gardens alone would not justify a reticulation system of this scale and the feasibility of the system will be a function of many other factors.

It is likely to be at least five years prior to construction starting if the system is to proceed at all.

Progress of the feasibility of this system should be monitored.

5.2.3 Groundwater

Groundwater could potentially be used to supply irrigation water. Water is currently pumped from a shallow aquifer (Q1) and used to maintain a water feature and to run a fountain in Top Lake.

As outlined in Section 5.1.1, irrigation demand is estimated at some 120 ML/year, with an average demand of 25 ML/month between December and March. For 8hr pumping cycles this equates to 30 L/sec.

An analysis of the potential for groundwater to supply irrigation suggests it is unlikely to be able to supply sufficient quantities at the rate required (see section 5.4.1).

The anticipated supply from a well completed in the shallow Q aquifers ranges between 0.5 – 3 L/sec, and without balancing storage, a rate of some 30 L/sec is needed to meet summer demand.

Whilst there is a potential of obtaining yields of above 10 L/sec from single wells completed in the underlying bedrock, the anticipated salinity is unsuitable, unless shandied with mains water or stormwater.

Based on available information, groundwater per se is therefore not considered to be suitable to replace potable water use. Additional investigations are required, particularly with the shandying option (see Section 5.4.1)

5.2.4 Conclusion – alternative irrigation sources

Stormwater appears to be the most appropriate alternative source of water to supplement the current reliance on potable water. Particularly with the large upstream catchment on First Creek.

Stormwater will need to be captured, treated and stored until it is required for irrigation. The size of the storage is of the order of 17 ML.

The next sections discuss the treatment and the storage requirements for stormwater so it can be reused for irrigation.

5.3 Treatment for reuse water

Stormwater treatment objectives will be sufficient treatment to enable storage of harvested stormwater. The best practice stormwater treatment objectives include: 80% reduction of total suspended solids, 45% reduction of total phosphorous and total nitrogen compared to typical untreated urban runoff.

To achieve this level of treatment a sequence of treatment measures are required as discussed in Section 4.1.

5.4 Storage of reuse water

Options for irrigation water storage include the underlying aquifer, surface storages and underground tanks.

5.4.1 Aquifer storage and recovery (ASR)

A desk top review of the hydrogeology was undertaken by accessing the State's drill hole data base and an unpublished hydrogeological report covering the Adelaide metropolitan area (Gerges, 1999).

The following wells were recorded as located within the Botanic Garden:

Well I.D.	Date Drilled	Depth (m)	SWL/Date (m)	Yield/Date (L/sec)	Salinity/Date (mg/L)	Status
6628-6	1914	6.9	3.7/1949	3.8/1949	940/1949	Operational?
6628-7	1914?	6.7				
6628-139	1914				1300/1914	
6628-140	1914				1200/1914	
6628-141	1944?				1270/1944	
6628-13307	1985	19	4.9/2003	3/1985	1150/1985	Operational
6628-13528	1985	18	5/1985	0.5/1985		
6628-13529	1985	18	5/1985	1/1985	1300/1985	

From the feedback at the recent workshop (16/04/03), it would appear that well 6628-6 is still operational, with a reported yield of 70,000 L/day- assuming 8hr pumping duration, this would be equivalent to 2.4 L/sec.

Wells recorded as located within the Zoological Garden:

Well I.D.	Date Drilled	Depth (m)	SWL/Date (m)	Yield/Date (L/sec)	Salinity/Date (mg/L)	Status
6628-108	1967	12.8	6.4/1967	4.4	1645/1967	Operational
6628-137	1975	16.5	7.6/1975	4/1975	1005/1975	Operational
6628-11489	1978	28	6.7/1980	3.2/1980	1272/1978	Operational
6628-11490	1972	18.30	5.9/1991	3.5/1980	1250/1988	
6628-15257	1990	30	7.2/1990			Backfilled
6628-18266	1996	19.8	8.0/1996	2/1996	2238	

A hydrogeological x-section derived by Gerges(1999) suggests the following sequence can be expected, with inferred thicknesses:

0 -15m: Quaternary Hindmarsh Clay -clay with interbedded sand and gravels (Q aquifers)

15 - 30m: Blanche Point Marl - clay with chert, marl, limestone

30 - 35m: South Maslin Sands

35- 40m: Clinton Formation - lignite and clay

40- 90m: Weathered Adelaidean Basement - mostly clay and clay bound gravel

90 - : Unweathered Adelaidean Basement -slate, quartz, dolomite, phyllite

Quaternary aquifers (Q1,Q2)

From the PIRSA drill hole database records summarised above, the shallow Quaternary aquifers at the Botanic Garden can be expected to yield between 0.5 to 3 L/sec. Note that of the 3 wells sited in proximity to each other (wells 13307,13528,13529) and to approximately the same depth (Q 2), only well 13307 had a reasonable yield of 3 L/sec. This suggests that the Q aquifer at the Botanic Garden is not extensive laterally, but is likely to be restricted to relatively narrow old river beds with a maximum thickness of 3-5m.

Salinity of the wells located within the Botanic Garden generally ranges from 1,000 to 1,300 mg/l and depth to water is about 4m.

In contrast, five Q 2 wells at the Zoological Garden have a consistent yield of some 3-4 L/sec, with salinity ranging from 1,000 to 2,200 mg/l.

Tertiary T1

From limited data, wells completed in the T1 aquifer are expected to yield 0.5 to 1.5 L/sec, salinity expected to range from 1,300 to 3,800 mg/L and depth to water 7 to 15m.

Adelaidean Bedrock

There are no wells drilled into bedrock in the general locality. Well yields are not known, but can be expected to range from 1 to +10 L/sec. Salinity can be expected to range from 1,500 to 2,500 mg/l.

5.4.2 Potential for ASR

Key factors in the viability of ASR include:

- the storage capacity of the aquifer, without causing environmental harm (eg water logging)
- rate at which the injected water can be stored and recovered from the aquifer
- the Recovery Efficiency, defined as the volume of water recovered suitable for the intended use expressed as a percentage of the volume of water injected
- the quality of the injected water, which cannot be worse than the receiving groundwater.

In this preliminary assessment of the ASR potential, the water quality of the injectant has not been considered.

Three are three potential aquifers that could be used for storage of irrigation water. These include (in order of increasing depth) the Q aquifers, T1 aquifer and Adelaidian bedrock. The potential for each is discussed below.

Q aquifers

The Q aquifers are considered to have limited storage capacity due to the anticipated narrow and thin (less than 5m thick)), channel like occurrence of the aquifer formation, and the relatively shallow water table. Injection and recovery rates of 3 l/sec can be expected, but if the aquifer is restricted to narrow old river beds, then it is unlikely that recharge volumes in excess of 50 ML/year can be expected. The Recovery Efficiency is expected to be greater than 75%.

T1 Aquifer

Whilst the T1 aquifer is expected to have a greater storage capacity than the Q aquifer, well yields are expected to be too low for a viable ASR scheme.

Adelaidean Bedrock

Based on the limited hydrogeological data, it appears that the Adelaidean bedrock offers the best potential for ASR, albeit untested, in terms of both storage capacity and well yield or rate at which water can be injected and recovered. The Recovery Efficiency is however expected to be the lowest of the 3 aquifers considered.

It should be pointed out that 50-100 ML/year ASR schemes utilising winter flows from Fifth Creek are currently being established in bedrock, approximately 10km to the NE of the Botanic Gardens.

Recommended Additional Investigations

In order of increasing cost, the following program of work is warranted. Whilst it is focussing on ASR, most of the program also applies for testing the potential of using groundwater shandied or supplemented by mains water:

Test the extent and suitability of the Q aquifer

1. Locate existing wells in the Botanic Garden, confirm status and review all available information, such as driller's lithological logs and operational performance. Order of magnitude cost = $1,000
2. Discharge test the operational wells to determine if the formation does not respond as a strip aquifer (ie aquifer is not restricted to a narrow channel). Order of magnitude cost = $3,000
3. Subject to positive discharge tests, drill one or two relatively cheap investigation holes to confirm the lateral extent of the aquifer, and discharge test the productive wells. Order of magnitude cost = $10,000
4. Develop a numerical model and predict extent of water level rise and lateral spread of the plume of injectant. Order of magnitude cost = $5,000
5. Carry out trial injection test with mains water or equivalent. Order of magnitude cost = $5,000
6. Develop and cost a concept ASR scheme. Order of magnitude cost = $5,000

Test the viability of the Adelaidean Bedrock

1. Drill an investigation hole to say 150m, and airlift test well yield. Order of magnitude cost = $15,000
2. Subject to adequate airlifted yield, discharge test well. Order of magnitude cost = $3,000
3. Subject to positive results, develop and cost a concept ASR scheme. Order of magnitude cost = $5,000

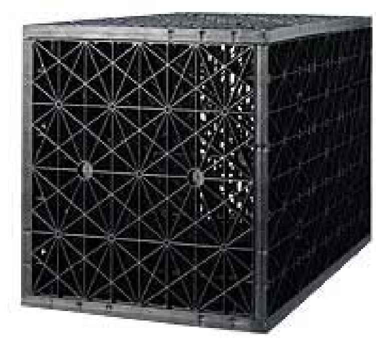
5.4.3 Other storages

Should ASR not prove viable there are alternatives for storage of irrigation water either above or below ground.

Surface lakes could be used as irrigation water storages, however, there are several constraints in the Botanic Gardens site, mainly space and aesthetics. There is little available space for a lake storage of sufficient size in or close to the Gardens. In addition, a lake used for irrigation storage will often be drawn down as water is used to irrigate. This can leave banks exposed for long periods during summer that can be unsightly.

For these reasons an above ground lake storage system is not recommended for the Gardens.

There are different options for underground storages. Tanks can be built as single tanks or as a number of smaller cells that are linked. The modular system of small cells allows storages to be easily suited to local constraints. Some systems also have load bearing capacity which make them suitable for construction under car parks or other open spaces (either vegetated or hard stand areas).



Example of Atlantis storage 'cell'

5.4.4 Conclusion of storage requirements

From analysis of the climatic conditions of the area and likely irrigation demand a storage of 17 ML is expected to enable the supply of 80- 90% of required irrigation water from harvested stormwater.

To achieve this quantity of storage there is potential to use an underlying aquifer, however further investigations are required to determine its feasibility (see Section 5.4.2 for recommended testing procedure).

Should ASR not be feasible, some of the required storage could be found using underground tanks that could be located in one central location or be distributed around the gardens. The most likely storage tanks will be modular in form and allow the tanks sizes to be tailored to particular areas. While it may be unlikely to be able to construct 17 ML of storage economically, 5 ML of storage for example, would enable up to 75% of irrigation demand to be met. Underground storage options should be further investigated if an ASR system is not viable.

6 WATERWAY REHABILITATION

The existing creeks through the Gardens are characterised by concrete lining with vertical sides. The form of the creeks was most probably a response to the flooding concerns through the Gardens.

The concrete lining provides a very efficient pathway for flows. This results in high flow velocities that carry pollutants downstream and prevent any material from settling onto the bed of the stream.

This concrete lining and current riparian form add little to the ecological health of the waterway or the ecology of the Gardens.

There are also safety concerns with the high velocities, the vertical sides of the waterway and easy access to the edges of the creeks. Downstream of the Gardens (in Botanic Park) the concrete lining is replaced with a more natural form, however, the high stream velocities and large flows have caused some locally severe bank erosion leading to near vertical stream banks up to four meters high, some areas with close proximity to walking and bike paths. These areas also present safety concerns for people using Botanic Park.

Should the retarding basin be constructed just downstream of Hackney Road to reduce the channel forming flows (up to 1 year average recurrence interval), there is an opportunity to replace the concrete lining with a more natural stream bed. A system of pool and riffle sequences and associated bank works would ensure the structural integrity of the creek during floods and also allow rehabilitation of the creek ecosystem.

6.1 Natural channel form

If concrete is to be removed along First Creek the waterway will require stabilisation from erosion of the bed and banks of the creek. This will require some flood retardation upstream of the gardens to reduce the frequency of bank full flows through the gardens (refer to Section 3.3), as well as controlled 'drop structures' down the bed of the stream.

The design of the stream cross section will be a shallow 'low flow' channel which will accommodate up to 1-year flows (see Figure 13). This part of the creek will be reinforced with dense riparian vegetation and regular rock riffles to locally control grade changes in the creek and armour the bed from erosion.

Flows above approximately a 1-year average recurrence interval will be directed (at controlled points) out of the low flow channel to an overland flow path that has a relatively smooth surface (eg. grass). These areas along the creek can be used for recreational purposes and can be landscaped into attractive areas while providing efficient delivery of flows during infrequent flood events. Connections from the creek to the overland flow path and returning to the creek will need to be designed to be stable during high flows. This may require some rock armouring and dense riparian vegetation. Provision a flood retarding basin and a high flow floodway are crucial elements in the development of a more natural channel form for the creek through the Gardens.

Separating the stream from the overland flow path are areas of riparian woodland. These areas offer an opportunity to introduce areas of different ecology into the Gardens, provide secluded areas along the overland flow path and stabilise the low flow channel banks.

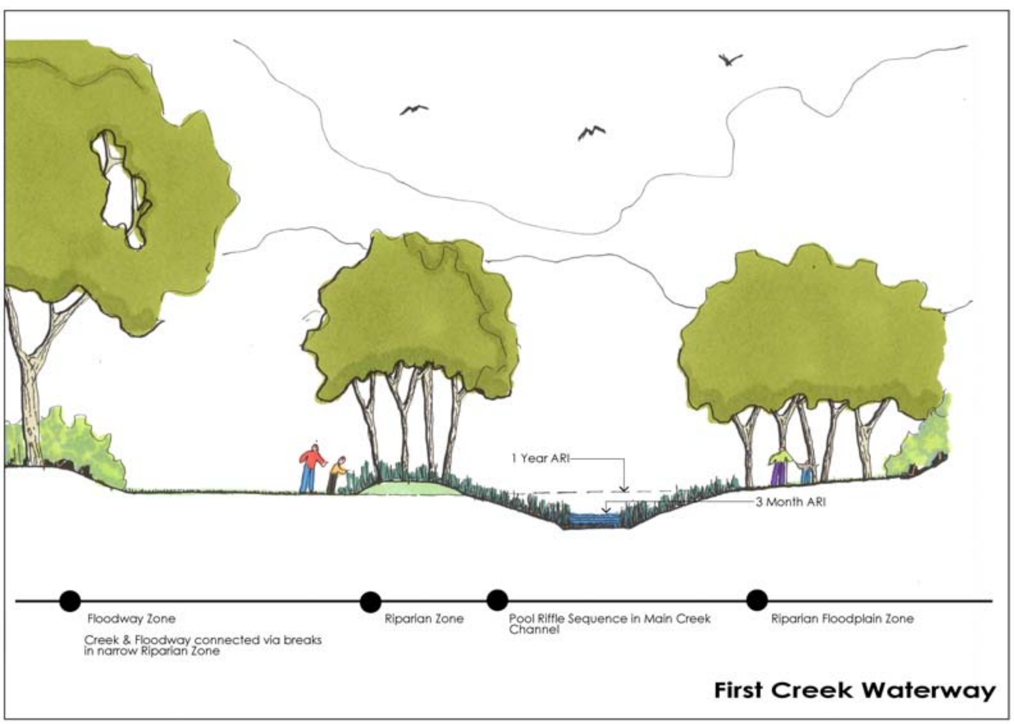


Figure 14 Cross section of proposed rehabilitated First Creek

6.1.1 Stream bed stabilisation

Drop structures (rock chutes) will be required along First Creek to prevent erosion of the creek bed because of the steep bed slope between Hackney Road and Torrens Lake. Without drop structures the bed is likely to erode and become more incised with eroded sediments being transported to Torrens Lake.

Drop structures can be constructed from local stone and be constructed to be sympathetic to the landscaping of the area (at slopes of between 1 in 12-15 downstream faces). In general, drop structures are constructed such that the crest of a lower drop will be at the same level as the toe of the higher drop structure. In this way flows are 'stepped' down the steep grade and the underlying bed is protected.

Bank erosion is evident along bends in First Creek, particularly in the lower section (in Botanic Park) close to Torrens Lake.

To improve safety and to prevent further erosion some stabilisation measures are required. Laying the banks back, reinforcing the tow of the banks and up the side to approximately the 1-year ARI water level and vegetating the banks with suitable plants will provide stability of the banks and improve safety along the creeks.

7 STAGING OF WORKS AND PRELIMINARY COST ESTIMATES

A recommended sequence of works is presented below that responds to the immediate flooding risk along Botanic creek and an upstream to downstream approach for the stream restoration works. Generally upstream works are required to protect the downstream waterways from flooding impacts as well as large loads of pollutants.

The suggested order of work is:

1. Upstream retarding basins on Botanic Creek
2. Modify outlet from Main Lake
3. Overland flow paths from Main Lake to First Creek
4. Flood retarding basin and wetland system on First Creek
5. Investigate underlying aquifers as storages for harvested stormwater
6. Rehabilitate First Creek
7. Investigate the health of Top Lake and the groundwater supplying it
8. Rehabilitate Botanic Creek between Top and Main Lakes.

The scale of works and indicative costs for each of these items is discussed below.

Upstream retarding basins on Botanic Creek

Upstream retarding basins could potentially reduce flood flow rates in Botanic Creek and therefore reduce the required capacity (and size) of an overland flow path from Main Lake. The retarding basin investigations should be given a priority as the extent of retardation will need to be accounted for during the design of the overland flow path.

Works to construct the retarding basins are expected to involve modification of the current culvert systems under the downstream roads. Road embankments are to be used as the retarding basin walls and ground surface levels will not be modified in the basins. Therefore, costs are expected to be limited to modifying the road culverts and cost approximately $30,000 for each culvert.

Modify outlet from Main Lake

Works to increase the reliability of the outlet of Main Lake to the underground pipe flowing to First creek (to reduce the incidence of blocking) are expected to involve construction of an overflow pit with a submerged outlet. This is expected to cost around $15,000. As part of these works, the estimated capacity of the outlet and pipe to First creek should be confirmed as it will also need to be known to design the overland flow path from Main Lake.

Overland flow paths from Main Lake to First Creek

Provision of a safe flow path for flood waters from Main Lake to First Creek is paramount to protecting the Gardens and neighbours from flooding during infrequent flood events. The design of the overland flow path and associated low flow channel will need to be incorporated into wider landscape plans for the Gardens to maximise the botanical value of the stream system and to determine an appropriate alignment of the stream bed.

Construction of the overland low path, low flow channel and entry into First Creek are estimated to cost approximately $100,000.

Flood retarding basin and wetland system on First Creek

There will need to be an integrated design of the retarding basin and stormwater treatment system for First Creek that incorporates the multiple objectives of flow control (to allow downstream waterway rehabilitation) and pollutant removal (to allow stormwater harvesting). The proposed site is small relative to the catchment size and has close proximity to the National Wine Centre. Consultation with affected stakeholders will be an important process to determine a suitable design that accommodates the required space for flood retardation and wetland treatment, maintenance access, visual impact and integration with the remainder of the Gardens.

Indicative cost estimates for the system are $150,000 for the retarding basin component (mainly earthworks and outlet structure), $400,000 for the wetland system (earthworks, structures and planting) and $150,000 for the gross pollutant trap (diversions and access routes).

Investigate underlying aquifers as storages for harvested stormwater

During the investigation of the retarding basin site on First Creek it would be pertinent to also investigate potential storages for harvested stormwater. This would allow the storage system to be constructed at the same time as the retarding basin and treatment system. There are a sequence of investigations proposed in Section 5.4 and the cost estimates range from up to $25,000 for the investigations. Construction costs for an aquifer storage and recovery system will be dependent on the outcome of further investigations.

Rehabilitate First Creek

Removing the concrete lining and rehabilitating the stream system along First Creek will be dependent on the upstream retarding basin and treatment system to control flows and reduce pollutant loads.

The sequence of rehabilitation works would likely be best from the upstream end of the reach working downstream. Preliminary cost estimates for the works are $500,000 and would involve the removal of the concrete lining, construction of rock chutes, earthwork to form the banks and floodplains, rock armouring of critical elements of the stream edges and revegetation.

Investigate the health of Top Lake and the groundwater supplying it

The health of Top lake and quality of the groundwater that feeds the lake will need to consider mixing in Top Lake and the impact of the groundwater quality on the health of the lake. Alternative recirculation techniques may need to be investigated. This study is expected to cost approximately $10,000.

Rehabilitate Botanic Creek between Top and Main Lakes.

The reach of stream between Top and Main Lakes could be rehabilitated following the investigation in the upstream retarding basins on Botanic Creek. The works would involve removal of the concrete and reestablishment of a more natural stream form. The works are estimated to cost approximately $25,000 for earthworks, stablisation structures and revegetation.

8 SUMMARY

This study recommends an integrated approach to the management of the waterways through the Adelaide Botanic Gardens that includes elements to:

- Reduce demand for mains water for irrigation
- Manage flooding impacts in and downstream of the gardens (particularly for Botanic Creek)
- Reduce pollutant transport to Torrens Lake
- Improve the biodiversity and aesthetic values of the waterways through the Gardens.

There are a number of work elements proposed in the report to improve the waterway management in the Gardens, these include:

1. Upstream retarding basins on Botanic Creek to reduce flow rates through the Gardens.
2. Modify the outlet from Main Lake to prevent blockages and ensure operation during floods.
3. Construct an overland flow path and low flow channel from Main Lake to First Creek to safely convey flood flows and to recreate a stream habitat.
4. Construct a flood retarding basin incorporated with a stormwater treatment system (GPT, sediment basin and vegetated wetland) on First Creek to reduce flood flow rates and remove pollutants, just downstream of Hackney Road.
5. Further investigate underlying aquifers to act as a storage for harvested stormwater (from the treatment system on First Creek) to be used as irrigation water, thus reducing mains water use.
6. Rehabilitation of First Creek by removal of the concrete lining and establishment of a pool and riffle stream system and associated overland flow path to manage large floods, recreate a stream habitat and increase biodiversity.
7. Other works including investigating the health of Top Lake and the groundwater supplying it and rehabilitating Botanic Creek between Top and Main Lakes.

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